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("Keegan Coater")
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COATING TRIALS ON THE KEEGAN COATER

INTRODUCTION

Coating trials were conducted on the Keegan coater to become acquainted with the operation and capabilities of the air knife, trailing blade, and reverse roll. The ease of operation, flexibility, control and variation of coat weight and design were among other things studied in these trials.

COATING WITH AIR KNIFE

Coating trials were conducted on the Keegan coater using the air knife to determine the effect of solids, viscosity, speed, air pressure, applicator roll speed and direction, wrap on applicator roll, and angle at which the air blast hits the coating on the coat weight. These data will be used for future reference so that we will be able to apply a certain coat weight with a minimum of experimentation.

COATING APPARATUS

The high pressure air for the knife was supplied by an Airways Sanitizor vacuum cleaner connected to a Powerstat for controlling the air pressure. The vacuum cleaner was connected to the air knife with one-inch diameter tygon tubing. The air knife opening was set at 0.008" with the ends blocked with masking tape. With this setup the maximum obtainable

RAW STOCK

The raw stock used in all of the runs was a 10-inch wide magazine grade coating raw stock (Kimfect) made by Kimberly-Clark. Basis weight of the raw stock was about 26 lb./25x38/500. The wire side was coated.

COATING COLOR PREPARATION

The pigments were dispersed in the following manner. The required amount of water and Quadrafos (2 meq./100 g. clay) were weighed in a 2-qt. Mason jar. While stirring vigorously with a "Lightnin" mixer, the kaolin clay (predispersed H. T. Clay produced by Minerals and Chemicals Philipp Corporation) was added slowly. The final solids content was 70%. The clay slip was stirred for about 15 minutes at top speed.

To disperse the TiO_2, the required amount of water and 1% Calgon T based on the weight of TiO_2 were added to the clay slurry. With constant stirring from the "Lightnin" mixer, the TiO_2 was added slowly. The ratio of clay to TiO_2 was 9 to 1. Final solids content was 70%. The TiO_2 was Reagent Grade produced by Glidden.

The Argentine casein was cooked in a 2000-ml. Erlenmeyer flask in a steam cone at 50-55°C. for 15 minutes and then 6% concentrated ammonium hydroxide based on the dry weight of the casein was added. The casein was cooked for another 45 minutes at 50-55°C. with agitation being supplied by a "Lightnin" mixer.

The coating color was made up in a one-gallon pail. The casein was added to the pigment slip in small increments to reduce the effects of casein shock. Agitation was supplied by a stirring rod driven by human power. The coating color was not screened. A preservative and defoamer were also added.

The formulations and viscosities of the coating colors are given in Table I.

TABLE I

COATING COLOR FORMULATIONS FOR AIR KNIFE

Identification	Pigment Ratio		Adhesive, %[a]		Solids	Brookfield Viscosity, cp.		
	Clay	TiO_2	Casein	Dow 630		60 r.p.m.	30 r.p.m.	12 r.p.m.
A	90	10	8	8	45	60	59.2	52.5
B	100	--	8	8	43	36.8	38.2	40.0
C	90	10	8	8	40	24.0	24.4	27.0
D	90	10	8	8	35	11.5	10.2	10.5
E	90	10	8	8	30	8.1	7.0	7.5

EXPERIMENTAL RESULTS

The raw stock was coated using many different combinations of air pressure, viscosity, solids, and other conditions. The first three mentioned seemed to have the most noticeable effect on coat weight.

The effects of air pressure on the coating weight are shown in Figure 1. The coat weight varies inversely with air pressure and the rate of increase of coat weight seems to increase as air pressure decreases. The

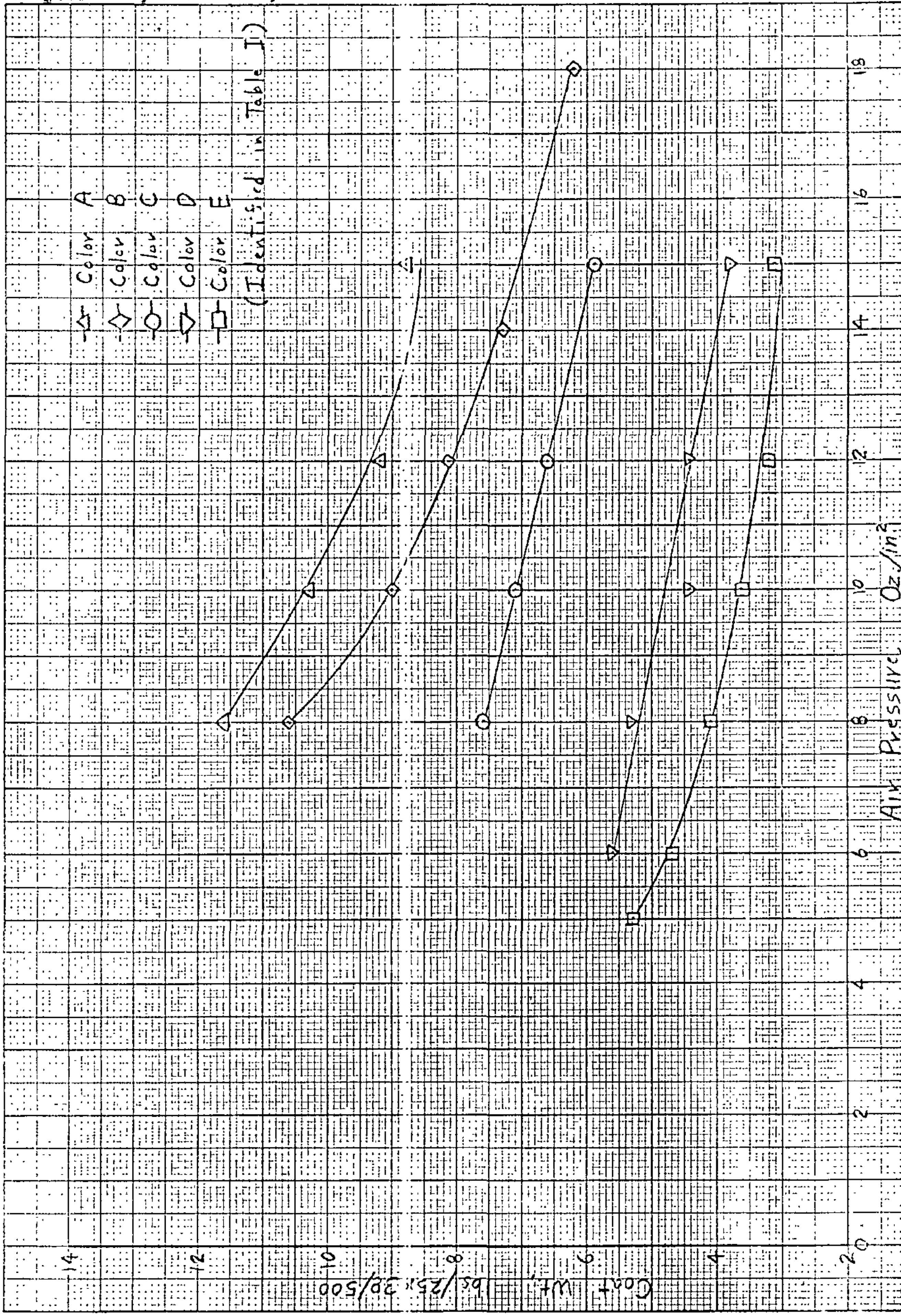


Figure 1. Effects of Air Pressure, Solids and Viscosity on Coat Weight

K&E 10 X 10 TO 1/2 INCH 46 1320
7 X 10 INCHES MADE IN U.S.A.
KEUFFEL & ESSER CO

coat weight seems to level off somewhat as the air pressure approaches 16 oz./in.^{2}. Varying the air pressure was quite effective in changing coat weight as can be seen in Figure 1. The variations are larger at the higher solids levels as would be expected. At any solids or viscosity level an air pressure change from 8 to 16 oz./in.^{2} would decrease the coat weight by about 25%.

As shown in Figure 1, the coat weight decreases with decreasing solids, but the decrease is not proportional. If the viscosity remained the same, the change in coat weight should be proportional to the change in solids. Not enough data was available to make an accurate estimation of the effect of viscosity on the coat weight. The amount of change of coat weight with a change in viscosity seems to be substantial. Effects of viscosity seem to be more pronounced at lower air pressures.

More data should be obtained on the effects of viscosity on coat weight. But for laboratory work several different air pressures could be used to obtain the proper coating weight. It would only take a minute at each air pressure setting to coat all the paper needed for testing. As shown in Figure 2, the angle at which the air blast hits the coating has some effect on the coat weight. The data in Figure 2 was obtained at different coater settings. They are meant to illustrate only the effect of knife angle on coat weight. All the points on any given curve were obtained at the same settings except for knife angle.

K+E 10 X 10 TO ½ INCH 46 1320
7 X 10 INCHES MADE IN U.S.A.
KEUFFEL & ESSER CO.

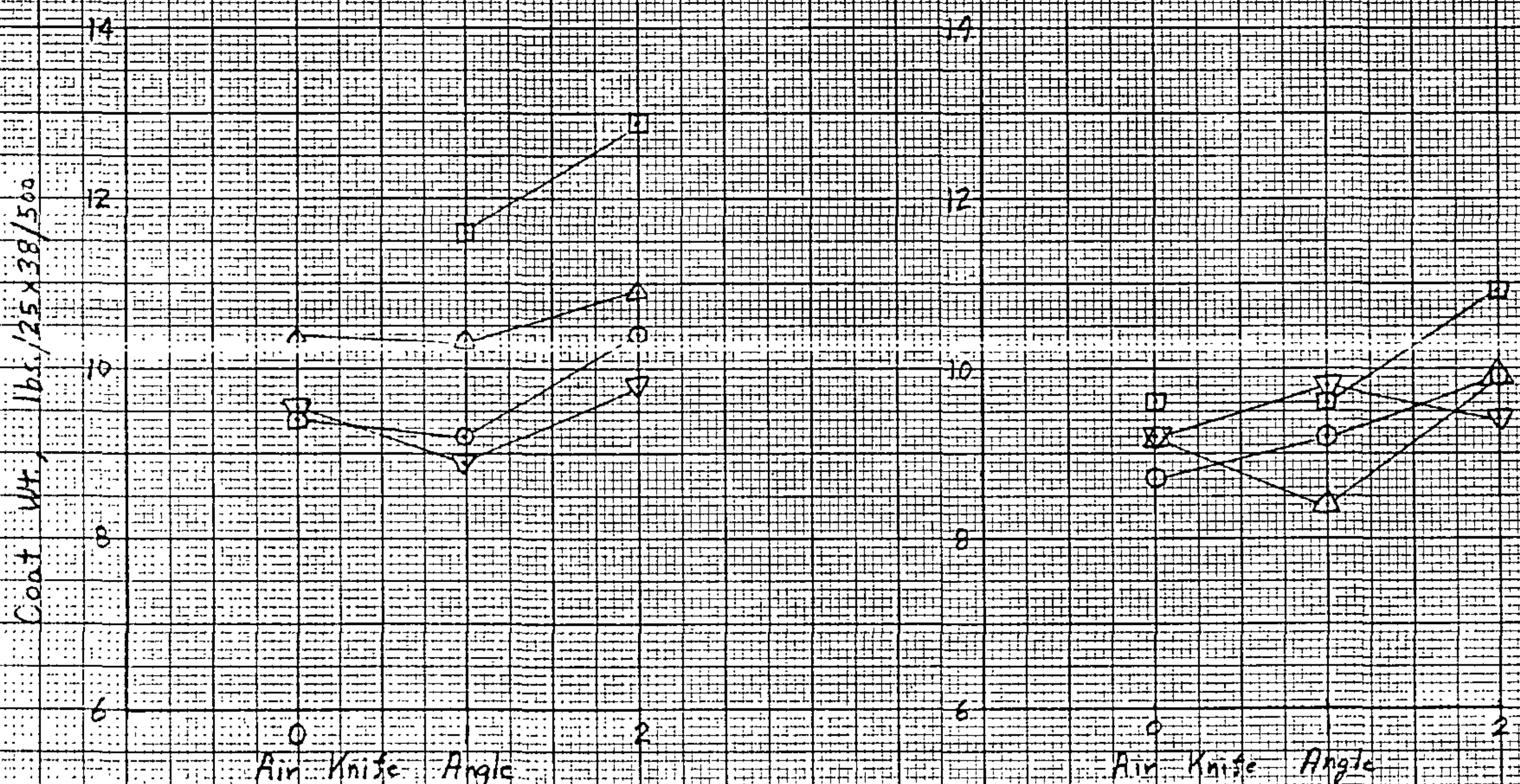


Figure 2. Effect of Air Knife Angle on Coat Weight

The knife angle of 1 seemed to be the most desirable setting. The setting of 0 did not work as well as 1 and 2 because the coating seemed to splatter and build up on the air knife. The 2 setting did not blow as much coating off as 1 and 0, so I chose the 1 setting. The air knife settings are marked on the air knife housing, but the angle at which the air blast hits the coating is not known. If the air knife opening was placed too close to the coating, the coating would build up on the air knife.

The speed at which the applicator roll turned did not make any difference in the coat weight unless it was turning so slowly that it would not transfer enough coating to the paper. Sufficient coating was transferred to the paper running at 117 ft./min. with the applicator roll turning at 33 ft./min. in the same direction as the paper. An applicator roll speed of 25 ft./min. was found to be sufficient for any speed with the possible exception of top speed with a very fluid coating color.

The direction which the applicator roll turned had a definite effect on the coating. When the roll turned the direction of the paper (forward), no difficulty was encountered. But, when the roll turned in the opposite direction of the paper (reverse) the coating would skip and have spots with less coating. The thin spots ran completely across the paper. The applicator roll may not have been picking up a continuous film of coating or the speed differential caused a large excess of coating to build up between the roll and paper causing the paper to lift up or bounce and break contact with the coating causing it to skip. Because of this difficulty, the applicator roll was used in forward gear for all the runs except for a couple in which the skips were discovered.

The amount of wrap of the paper on the applicator roll did not seem to have any effect on the coat weight as shown in Figure 3. The numbers indicate arbitrary settings made on the coater with the amount of wrap increasing with the number. In the 1 position the paper just touches the roll and in the 8 position the paper wraps 7/16 of an inch (22°) around the 2-5/16-inch roll. For most of the coating work a wrap setting of 2 was used because it seemed to do a good job of coating.

The coating speed did not have much effect on the coat weight as can be seen in Figure 4. The coat weight increased slightly with increased speed but this increase may not be real.

Most of the coating was done at a speed of around 60 to 80 ft. per minute. The drying capacity of the drying system was not high enough to dry heavy coating at low solids running at speeds of 100 or more ft./min.

To obtain a greater drying capacity, a 10-inch fan was placed by one of the openings in the back side of the coater in the drier section. The fan was placed at the same height as the paper and was run at the fast speed. The fan increased the drying capacity approximately 50% and allowed an increase in speed of approximately 20 ft./min.

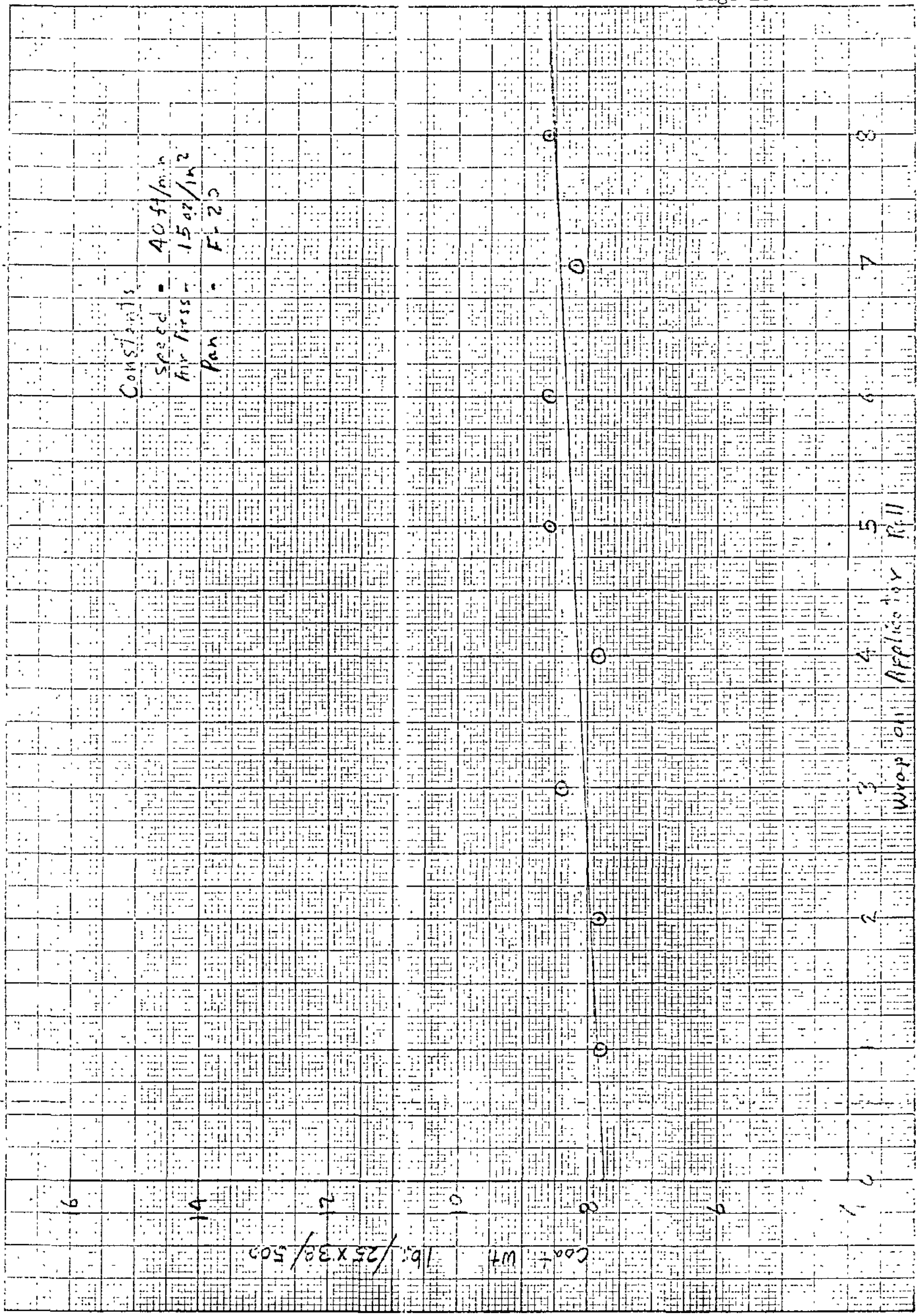


Figure 3. Effect of Wrap on Applicator Roll on Coat Weight.

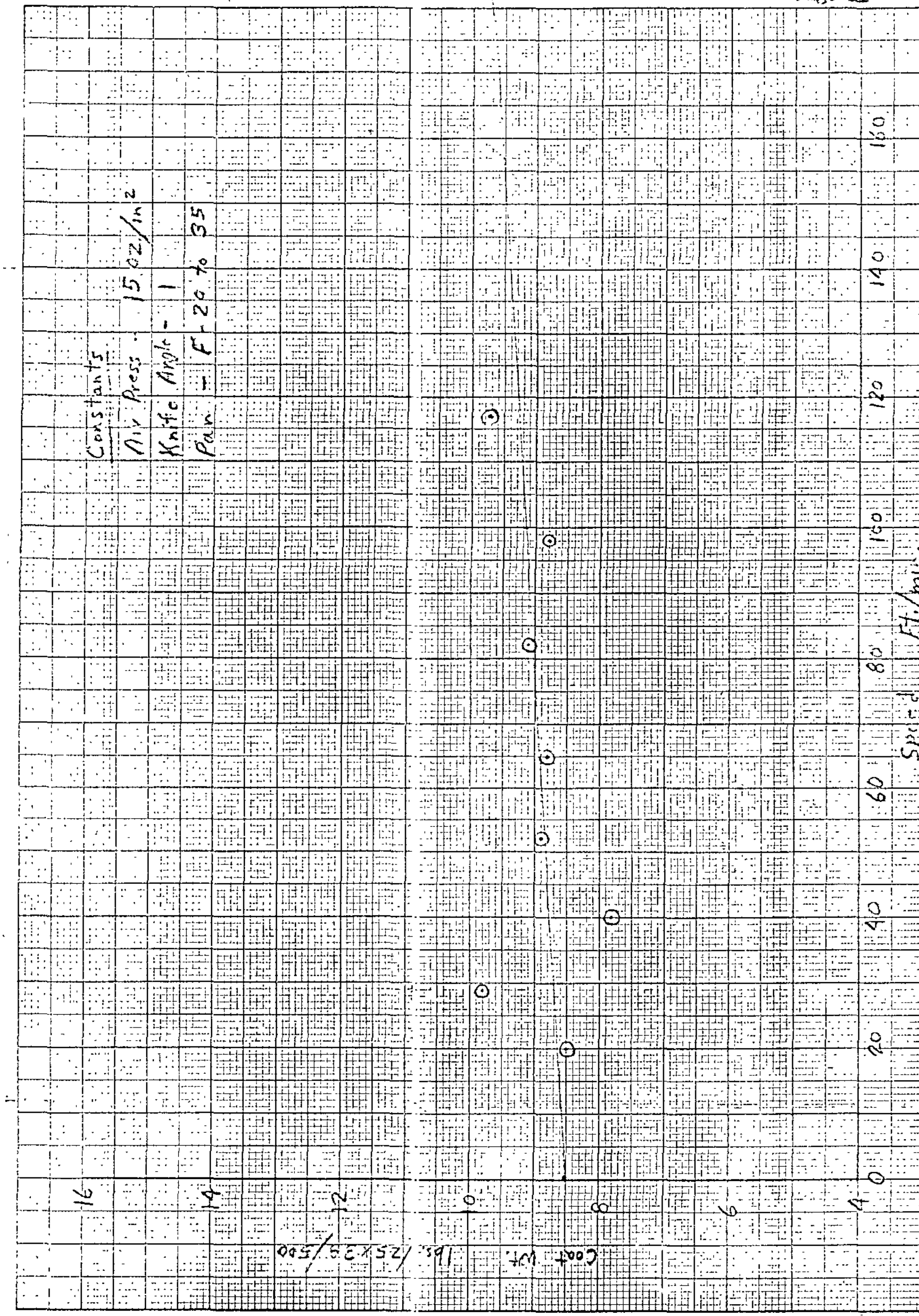


Figure 4. Effect of Speed on Coat Weight

10 X 10 TO THE ½ INCH 358-11
KEUFFEL & ESSER CO. MADE IN U.S.A.

SUMMARY

The air knife seemed to work very well and offered good control of coat weight by changing solids and/or air pressure. Just by varying the air pressure, the coat weight was changed by 2 or more pounds. At higher solids the change was even larger.

The air knife puts on a nice even coating free from streaks. The air knife is easy to set up and operate. The viscosity range at which the air knife can operate is fairly wide with low viscosity coating colors being the most suitable.

Its drawbacks are few--for instance, clean-up requires more time than the trailing blade, although it is not very time consuming. The drying capacity of the drier section is not quite large enough to dry the heavy coatings at speeds over 100 ft./min.

Taking everything into consideration, the advantages or good points seem to far outweigh its weak points.

COATING WITH TRAILING BLADE

Coating trials were conducted on the Keegan coater using the pond-type trailing blade coating method. The effects of speed, angle of blade, pressure on blade, and solids were studied.

COATING APPARATUS

The trailing blade coater consists of a 12 by 1-3/4-inch steel blade held between a 12 by 1 by 1/4-inch aluminum plate and a pivotable bar that allows the blade to be rotated into the backing roll for operation and rotated away for cleaning. The blade extension was set at 7/8 inch. The pressure on the blade was controlled by two turnbuckles, one on each side of the trailing blade frame. The trailing blade frame was connected to the main frame by a bolt on each side about which the blade frame could pivot. The point at which the end of the blade completely touches the paper was taken as the starting point for determining pressure on the blade. Pressure was described as number of turns of the turnbuckle past the starting or reference point. The turnbuckle contained 32 threads per inch.

The blade was operated at either a 30 or 45° angle with the paper. A ball and socket type catch arrangement controls the angles so they can be duplicated with no difficulty. The wing nuts on the ends of the rod which the blade mechanisms is attached to should be very tight before coating so as to keep the blade from rotating when high blade pressure is applied.

The coating was applied to the paper by using a squeeze bottle to spread the coating evenly over the width of the blade. Some of the coating tended to run off the edge of the paper and onto the backing roll, but this did not cause any difficulties because of the short runs.

The raw stock was the same as that used for the air knife coating trials.

COATING COLOR PREPARATION

The coating colors were made up in the same manner as described for the air knife coatings with the exception of the cooking of the starch. The starch (Superfilm 40 produced by Stein-Hall) was cooked up at 25 to 30% solids for 1/2 hour at 90 to 95°C. in the Corn Industries viscometer.

The formulations and viscosities of the coating colors are given in Table II. The coating colors will be identified by their identification letters supplied in Table II.

TABLE II

COATING COLOR FORMULATIONS FOR TRAILING BLADE

Identification	Pigment	Adhesive, %[a] Superfilm 40	Adhesive, %[a] Dow 630	Solids	Viscosity, cp. Brookfield 60 r.p.m.	Viscosity, cp. Brookfield 30 r.p.m.	Viscosity, cp. Brookfield 12 r.p.m.	Viscosity, cp. Hercules 1150 r.p.m.
F	H.T. Clay	13	2	55	1900	3000	5750	122
G	H.T. Clay	11	3	57	3170	4700	8500	154
H	H.T. Clay	11	3	60	3920	6240	12,500	214
I	H.T. Clay	3	12	65	1750	2720	5250	380

[a]Percentage based on the weight of pigment.

The Hercules rheograms for those colors given in Table II are found in Figure 5. According to the Hercules rheograms, Color I seemed to be a little dilatant while the other coating colors were thixotropic.

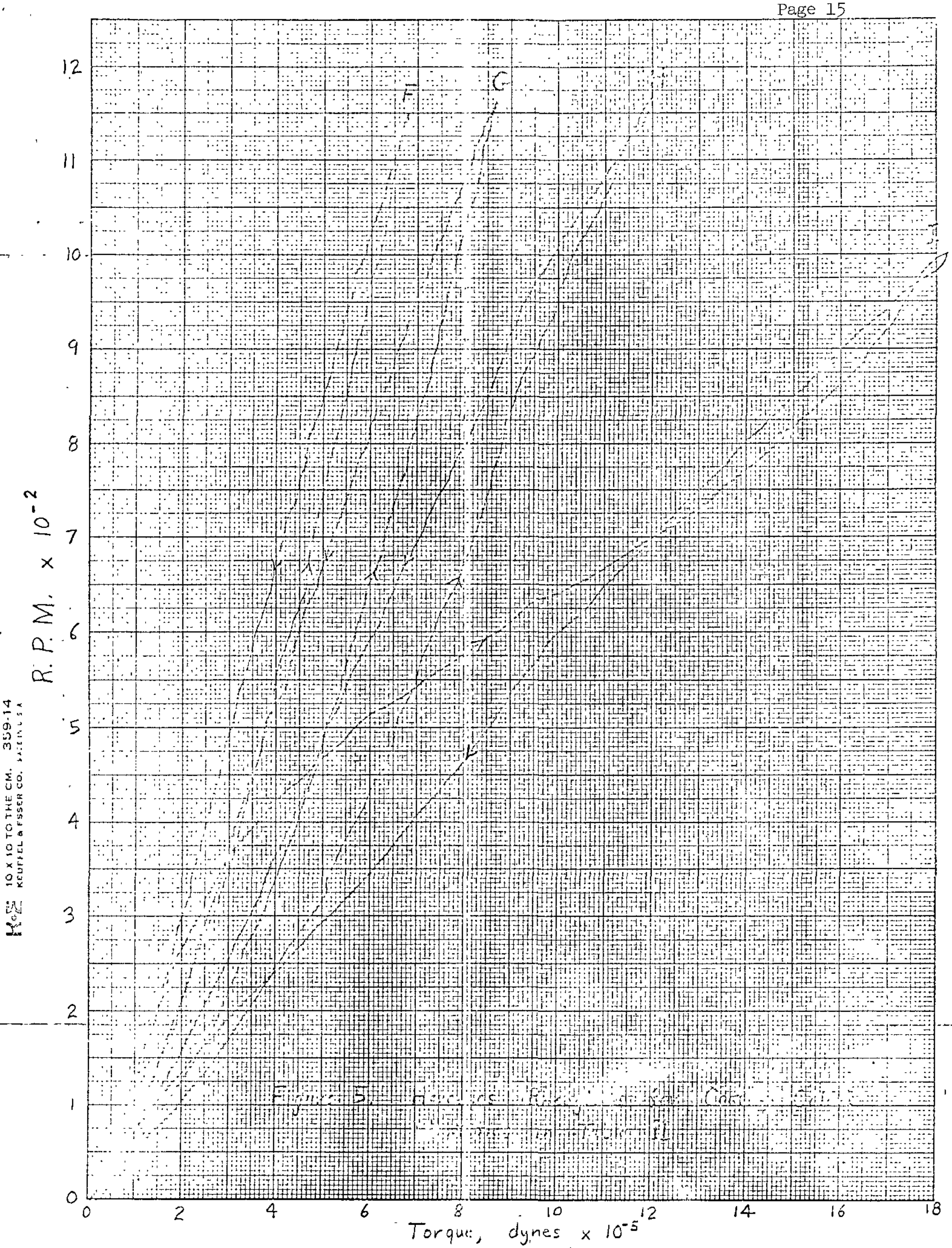

R. P. M. x 10^-2
Torque, dynes x 10^-5
F
G
0
1
2
3
4
5
6
7
8
9
10
11
12
0
2
4
6
8
10
12
14
16
18
10 X 10 TO THE CM. 359-14
KEUFFEL & ESSER CO.

Figure 5. [illegible]

EXPERIMENTAL RESULTS

The raw stock was coated on the wire side using different combinations of speed, blade angle, blade pressure, and solids. The effects of viscosity were not studied because different coating formulations having the same viscosity at low rates of shear may have completely different flow characteristics at higher rates of shear. An example of this would be Colors F and I. Both have approximately the same Brookfield viscosities, but the Hercules rheograms indicate a completely different flow curve especially at higher shear rates. The shear rate obtained when coating with the trailing blade was not known and probably would be much higher than that measured on the Hercules viscometer and therefore an accurate measurement of viscosity could not be made. Also, the increase or decrease in coat weight due to a change in viscosity could not have been significantly measured due to the changing basis weight of the raw stock and low coat weights applied by this method.

The effects of web speed on the coating weight are shown in Fig. 6. Web speed did not seem to have much effect on the coating weight, especially with the blade at the 45° angle. However, a slight increase in coat weight with an increase in speed was noted with the blade at the 30° angle, but for all practical purposes the increase was negligible. If the blade angle was decreased, the effect of speed on coat weight would probably be more pronounced because of the lifting action of the coating color on the blade.

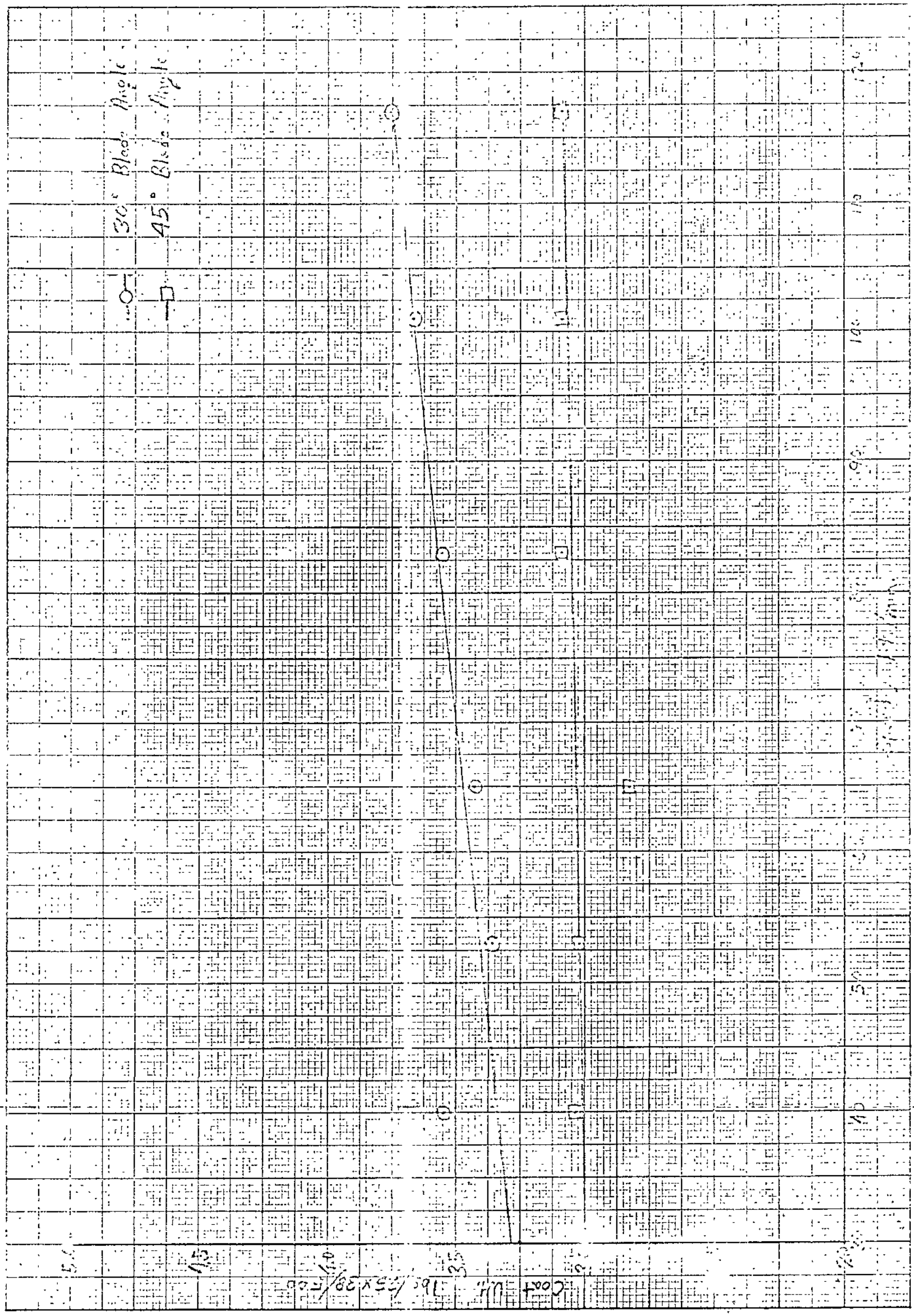


Figure 6. Effect of Coating Speed on Coat Weight

10 X 10 TO 1/2 INCH 46 1320
7 X 10 INCHES MADE IN U.S.A.
KEUFFEL & ESSER CO.

The effect of the angle at which the blade contacts the paper on the coat weight is shown in Figures 7 and 8. The coat weight increases with decreasing blade angle. The increase amounts to about 10 to 20% with a decrease in blade angle from 45 to 30°. The 30° blade angle seems to do a better job of coating. The blade angle could be reduced to about 20° if a heavier coating is required, but in that position the coating would have to be poured on to the paper instead of the blade because of the vertical position of the blade.

The effects of blade pressure on the coat weight are shown in Figures 7 and 8. Blade pressure has a marked effect on coat weight, especially at low and high pressures. The coat weight seems to be at a minimum at about 3 to 6 turns of the turnbuckle. The coat weights seem to be more predictable in this range. At very low pressures, the coat weight would be very hard to control because of the rapid change in coat weight with small changes in blade pressure. The blade pressure adjustment is described in the description of the trailing blade.

The increase in coat weight with increased blade pressure past about 5 turns may have been caused by a buildup of coating on the backing roll caused by the excess coating running off the paper and on to the roll. Another possible reason may be that the higher blade pressures cause the blade mechanism to rotate slightly thereby reducing the blade pressure and angle.

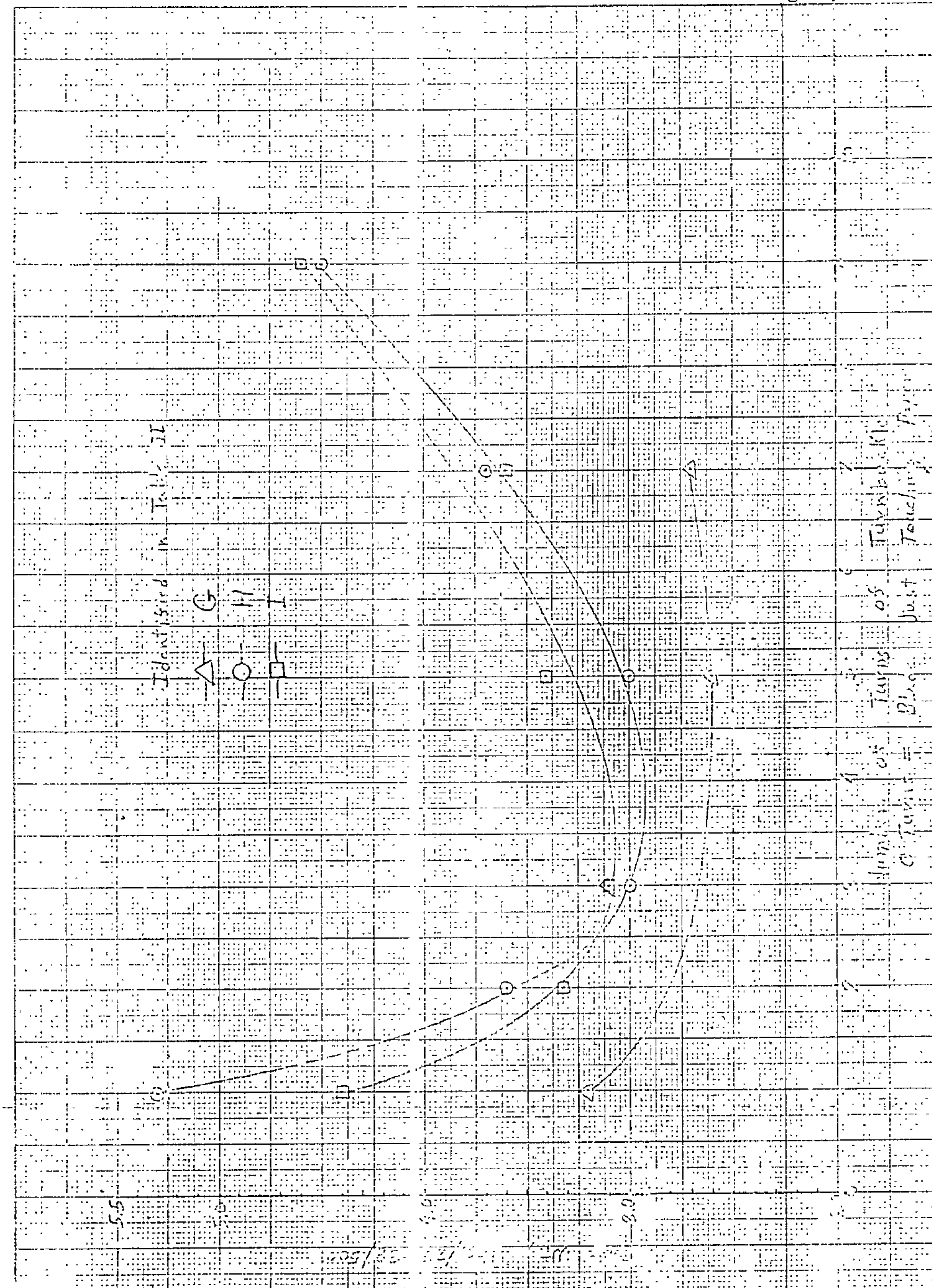


Figure 7. Effects of Blade Pressure and Solids on Coat Weight at 45° Blade Angle.

K&E 10 X 10 TO THE CENTIMETER 46 1510
18 X 25 CM
KEUFFEL & ESSER CO.

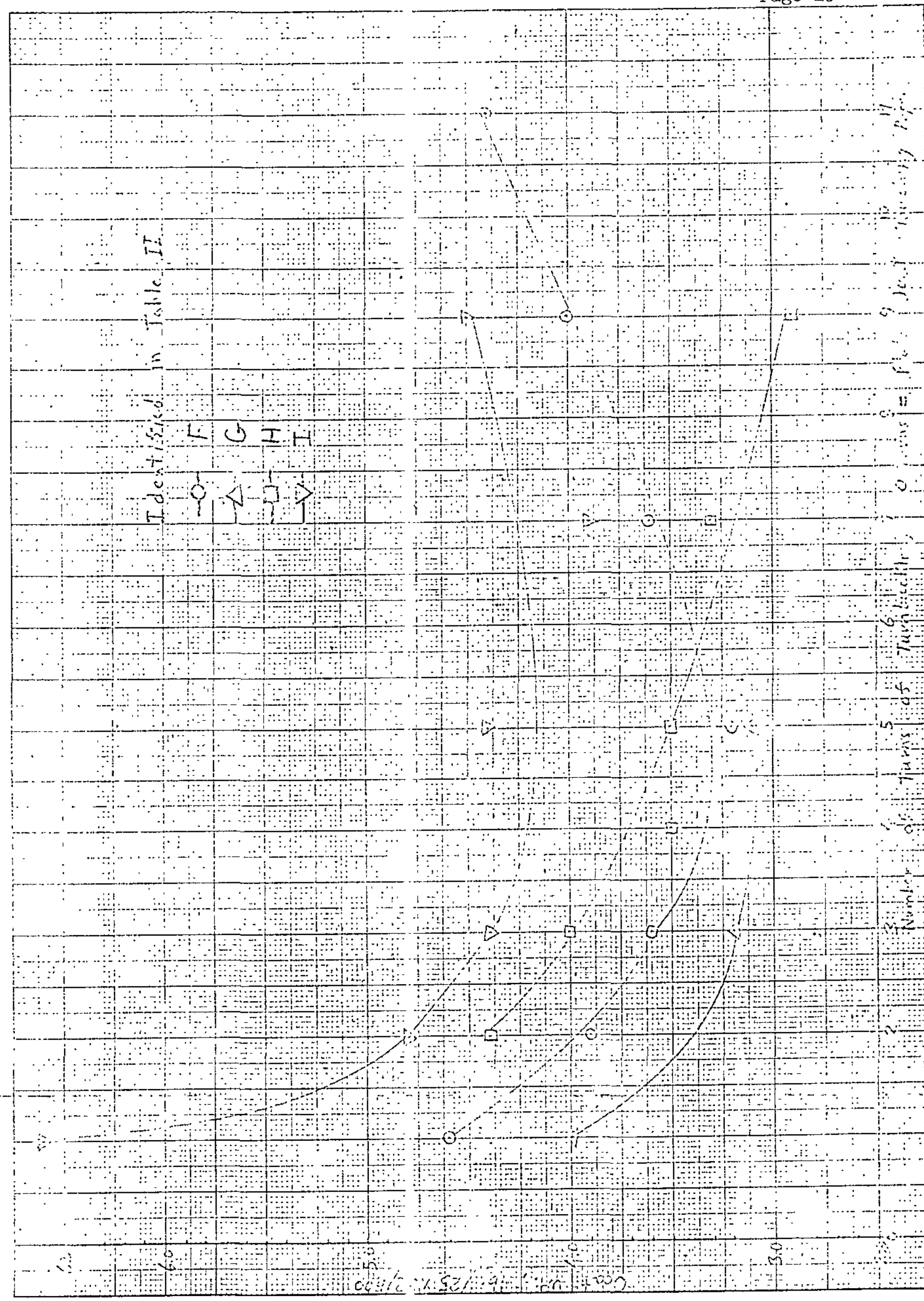


Figure 8. Effects of Blade Pressure and Solids on Coat Weight at 30° Blade Angle.

The solids content of the coating color has a marked effect on the coat weight as can be seen in Figures 7 and 8. The coat weight increases with increasing solids content. Some of the data do not indicate this, but those variations may be due to changes in basis weight of the raw stock. The basis weight of the raw stock was found to vary about one pound from roll to roll and may vary that much within the roll.

From the variations in coat weight seen in Figures 7 and 8, it is quite evident that close control of coat weight would be difficult. The coat weight curves give an approximate range of coat weight which can be obtained under certain conditions. Coating a different raw stock under the same conditions would probably give a different coat weight because of changes in absorbency and smoothness of the raw stock. However, these raw stock changes would probably not alter the coat weight to any great extent.

Some changes could be made to improve the application of coating by the trailing blade method. To keep the coating from running off the ends of the blade, small dams could be built. When coating for any length of time, the coating begins to build up on the rubber backing roll. If the coating built up too much, an uneven coating would be applied across the paper. The coating seemed to be a little heavier right near the edges of the paper during short runs. Dams would eliminate this problem.

An increase in coat weight could be accomplished by installing a more flexible blade with a longer extension. The present blade could be extended only 1/4 inch more than the present 7/8-inch extension used for these trials.

An inverted blade could be set up on the coater at the air knife location. The applicator roll could be used to apply the coating to the paper. The rubber backing roll used for the trailing blade could be changed around and used with the inverted blade. This method would allow the coating to be in contact with the paper for a longer time and increase coat weight. However, this method would be limited to lower viscosity coating colors than the puddle-type trailing blade. The applicator roll would not pick up the coating color if it is too viscous.

A more positive and reproducible way of controlling blade pressure should be installed on the trailing blade. An air cylinder type of pressure setup would work very well. This would eliminate the guesswork involved in setting the blade pressure by the present method. The blade could be cleaned between runs and set at exactly the same pressure. A numerical value could be assigned to the blade pressure.

SUMMARY

The trailing blade unit has its advantages and disadvantages as do the other methods of coating. Some of the advantages are speed, ease of cleaning, simplicity, and small amount of coating color required. The coater seems to work better when running at a fast speed. The blade and roll can be cleaned very easily and quickly. The blade is easy to operate, but does require alignment of blade and adjustment of tension on the blade. Only a small amount of coating color is required in comparison to the other methods of coating available on the coater.

Some of the disadvantages are low coat weight, lack of control of coat weight, coating color buildup on the roll, and some streaking. The maximum coat weight obtained even at 65% solids was less than 5 lb. except when the blade pressure was very low. The coating color builds up on the backing roll when operated for any length of time. This could be corrected by the use of dams on the blade. Some streaking was noted, but this can probably be corrected by passing the coating color through a 200-mesh screen. The present mechanism for controlling blade pressure should be changed to a more reproducible mechanism such as air cylinders.

The advantages, however, seem to outweigh the disadvantages. Methods have been suggested for correcting these weaknesses.

COATING WITH REVERSE ROLL

Coating trials were conducted using the reverse roll coater to become acquainted with its capabilities such as control of coat weight, effect of solids and viscosity. The amount of data compiled on the apparatus is not very complete, but it indicates some of its strong points and weaknesses.

COATING APPARATUS

The reverse roll coater consists of a motor driven metal roll and a free wheeling rubber roll. Both rolls are connected to the same frame with the metal roll being solidly mounted. The rubber roll is mounted in movable slides with screw-type adjustments on each end for adjusting clearance between the two rolls. The speed of the motor is rheostatically controlled on the main panel.

A doctor blade is located on the reverse metal roll. Each end is bolted down by a spring, washer, and wing nut in that order. The more the wing nut is tightened, the tighter the doctor blade is pushed against the metal roll. The doctor blade scrapes the coating off the reverse roll after it has removed it from the paper and the coating runs back into the pan and is reused. Mounted right on the doctor blade is a metal bar which contains seven evenly spaced Allen screws that are used for equalizing the blade pressure the length of the metal roll.

The coating was applied to the paper with the applicator roll running at 25 ft./min. in the forward direction. The reverse roll was running at 65 ft./min. This roll speed was found to be sufficient when the paper was running at 53 ft./min.

The roll settings are difficult to describe because they were made by sight and feel. A good coating was obtained over a very narrow range when the reverse roll was in contact with the paper. When the roll got a little loose, an uneven coating appeared with alternate heavy and light spots. This was caused by the rubber backing roll being out of round. The uneven coating would disappear as soon as the reverse roll was brought into complete contact with the paper. The adjustment screw could be tightened about 1/4 of a turn from this point. In that position the motor on the reverse roll was pulling fairly hard. Several different settings were tried between the loose and tight positions.

COATING COLOR PREPARATION

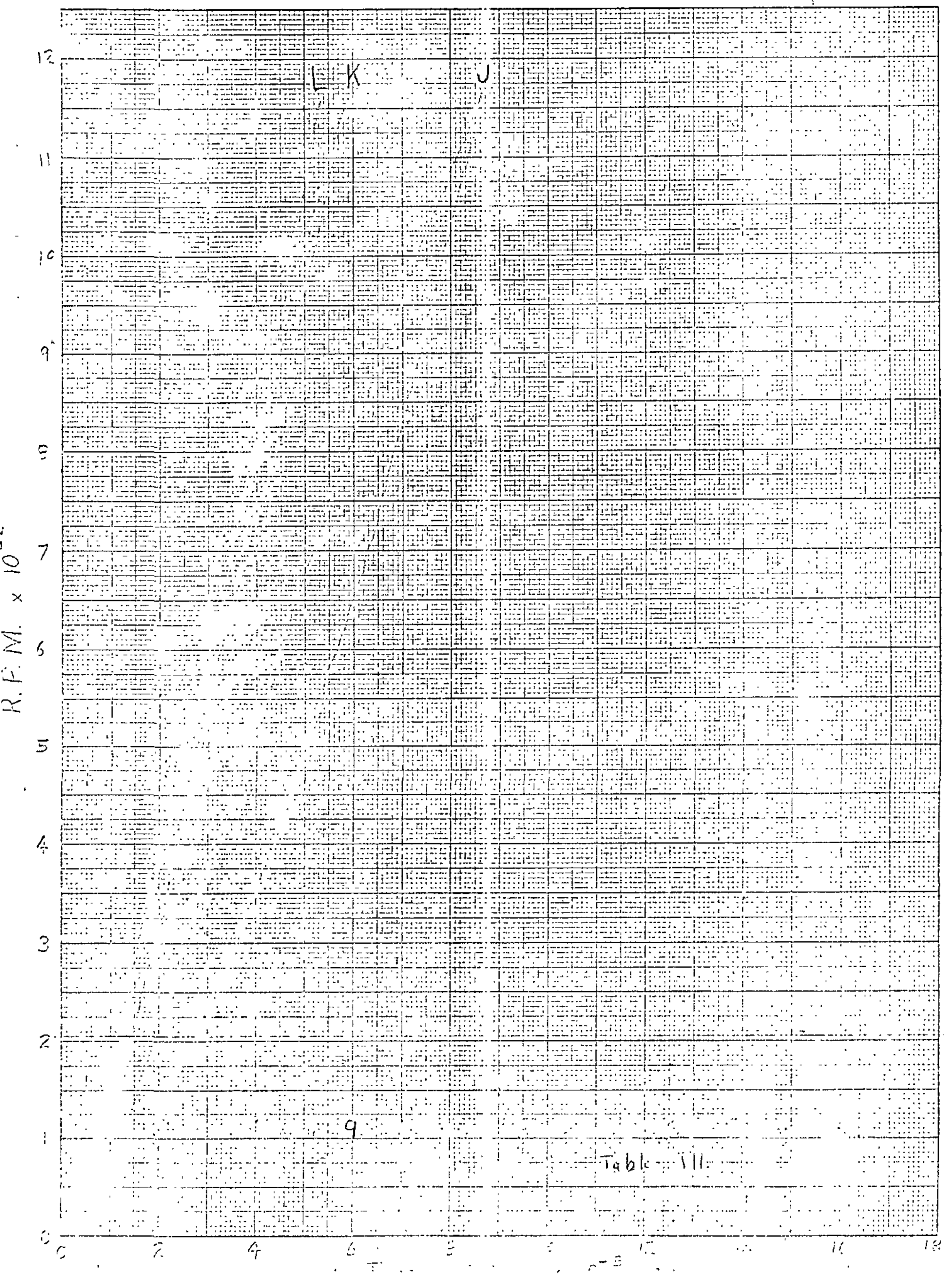
The coating colors were prepared in the same manner as described in other sections of this report. The formulations and viscosities of the coating colors are given in Table III.

TABLE III

COATING COLOR FORMULATIONS FOR REVERSE ROLL

Identification	Pigment	Adhesive, %		Solids	Viscosity, cp.			
					Brookfield			Hercules
		Superfilm 40	Dow 630		60 r.p.m.	30 r.p.m.	12 r.p.m.	1150 r.p.m.
J	Pred.H.T.Clay	11	3	57	3170	4700	8500	154
K	" " "	11	3	55	1250	1800	3450	104
L	" " "	11	3	50	354	500	950	95

Hercules rheograms for the coating colors in Table III are found in Figure 9.



10 X 10 TO THE CM. 359-14
KEUFFEL & ESSER CO.

EXPERIMENTAL RESULTS

Color J was the first coating color used for coating by this method. The coating color was quite viscous and did not work very well. The applicator roll would not pick up the coating color because it would not flow to the roll. Consequently, no data was obtained on this coating color.

Color K was less viscous and worked better although it was still a little too viscous to flow easily under low shear rates. Because of its high viscosity, the applicator roll transferred a large excess to the paper and the doctor blade became excessively flooded. The doctor blade did not scrape the roll completely clean and because of this the coating on the paper had some streaks. While trying to correct these faults most of the coating color was used up and only a small amount of data was obtained.

Color L was fairly fluid and was much easier to work with. The coating color did not build up on the doctor blade as much as with Colors J and K. Because of its lower viscosity it quickly flowed off the roll and back into the pan. The blade did not completely clean the roll but with a few adjustments it was made to clean the roll fairly good with the exception of one spot. The blade was slightly nicked at that spot. Before using this coating color, the roll was run for two hours with the blade in contact which seemed to eliminate some of the small irregularities.

Several different roll pressure settings were tried several times each to determine the amount of control and reproducibility of coat weight available with the reverse roll. The data indicated that the coat weight could not be controlled to any extent by changing the roll pressure. Using

Color L at different roll pressure settings, a variation of from 4.9 to 5.5 lb. was obtained at 50% solids. Coating Color K gave a coat weight of about 6.5 to 7.0 lb. Some of the increase in coat weight was due to the solids increase, but the increase was too large to attribute to the solids increase alone. Some of the increase may have been due to the doctor blade not cleaning the metal roll completely. The basis weight of the paper may have varied considerably, as much as one pound, from run to run.

The higher viscosity of Color K may have increased the coat weight a very small amount. The viscosity of the coating color should not have much effect on the coat weight because of the stationary position of the rolls. The way the reverse roll coater is set up, it works in a manner similar to a size press and smoothing roll.

Adjusting the solids content would be the best way of controlling coat weight. Not much data is available on the influence of solids, but it should be almost proportional to the change in solids. The coat weight obtained with Color L at 50% solids should be used as the basis for any adjustments in coat weight by changing solids.

SUMMARY

The reverse roll coater (as it is called by its manufacturer) has many weaknesses and very few strong points, if any, in its favor. Some of its weak points are as follows.

The lack of control of coat weight is one of its greatest faults. The only method of changing the coat weight is by changing solids content.

The design and workmanship of the reverse roll coater leaves much to be desired. The rolls are slightly out of round and the doctor blade does not completely clean the metal roll causing streaks in the coating. The coater is not actually a reverse roll, but more like a squeeze roll with the rolls turning in the same direction.

The coating did not look very good to the eye and had some streaks in it. A microscopic examination of the coating indicated that the fibers were completely covered and the coating looked fairly good with the low spots filled in.

This coating apparatus is the least desirable of the three methods discussed in this report.